# RESOLUTION OF WINTER MINIMUM FLOW ISSUES AT CONOWINGO DAM

**Summary of Study Findings and Recommendation**

## POWER PLANT RESEARCH PROGRAM

**February 1998**

# FOREWORD

Versar Inc., prepared this report, *Resolution of Winter Minimum Flow Issues at Conowingo Dam* ***n*** *Summary of Study Findings and Recommendation*, at the request of Dr. Richard McLean of the Maryland Department of Natural Resources, Power Plant Research Program under contract number PR91-047-001. The report summarizes the findings of a five-year study of the effect of various winter flow regimes on the macroinvertebrate community downstream of the Conowingo Hydroelectric Facility and recommends a winter flow regime appropriate for protection and enhancement of aquatic resources below the dam.

# ABSTRACT

The effect of various river flow regimes as provided by releases through the Conowingo Hydroelectric Station in winter on Susquehanna River aquatic resources downstream of the dam was evaluated over five years. Three release flow regimes were studied: a continuous flow of 3,500 cfs; an intermittent flow of 3,500 cfs; and no release. Monitoring the effect of these flow regimes on aquatic macroinvertebrate communities inhabiting two substrate types (bedrock and gravel) indicated that the no flow condition was detrimental. Results support a recommendation that a minimum flow of 3,500 cfs be provided in winter months at least intermittently (cessation of flow permitted for up to 6 hours followed by an equal or longer period of minimum flow) and provide the basis for resolution of the sole remaining environmental issue raised during the 1988 relicensing of the facility.

# EXECUTIVE SUMMARY

The Philadelphia Electric Company (PECO) has historically operated the Conowingo Hydroelectric Facility as a peaking facility, generating near capacity at times of high demand (weekdays) and generating little or no electricity when demand is typically low (nights and weekends). During periods of low river flow, the consequence of this operational regime was that virtually no water would be released from the dam during off-peak periods. When PECO applied to the Federal Energy Regulatory Commission (FERC) for renewal of their operating license in 1976, the impact of total plant shut-down on aquatic resources in the 10-mile river reach downstream of the dam was identified as a major issue by state and federal agencies and non-governmental organizations. Disagreements arose among PECO, state and federal agencies, and non-governmental organizations over the extent of impact and over the possible measures that should be taken at Conowingo Dam to alleviate impacts and enhance resources. After more than a decade of negotiation and litigation in FERC proceedings and recognizing the likelihood of continued expensive litigation, PECO, the State of Maryland, and other parties in the licensing process reached a settlement agreement in 1988 on three broad issues: 1) minimum water flows needed to protect and enhance downstream habitat and aquatic resources; 2) measures necessary to ensure that water quality requirements would be met; and 3) steps needed to foster anadromous fish restoration. By the summer of 1988, implementation of most portions of the agreement was well underway.

Regarding minimum flow requirements, substantial site-specific data available from studies sponsored by Maryland Department of Natural Resources, Power Plant Research Program (PPRP) and PECO provided a means of establishing appropriate minimum flow levels for the spring, summer, and fall months. These flows were proposed in the settlement agreement, accepted by all the parties involved, and have been in place since 1988. However, one issue left unresolved in the 1988 agreement was what level of minimum flow was necessary during winter months to protect and enhance aquatic resources. All parties agreed that insufficient information was available from which to establish necessary winter flow levels, and agreed that the state would sponsor a study to provide that information. The study examined the effects of three different winter flow regimes on the benthic macroinvertebrate community below the dam. Macroinvertebrates consist of aquatic insects and other small organisms that are sensitive to changes in environmental conditions and are also important food items for many important fish species. Results of the study were to be used by PPRP and PECO to select the appropriate winter minimum flow regime. This report provides a summary of the five-year study's findings and a recommendation for the appropriate winter flow regime.

Three potential winter flow regimes were studied from 1989 to 1993:

- a continuous minimum flow of 3,500 cubic feet per second (cfs);

- an intermittent minimum flow of 3,500 cfs (where cessation of flow is permitted for up to 6 hours followed by an equal or longer period of minimum flow, for a maximum of 12 hours off in a 24 hour period); and

- no minimum flow (under which the plant could shut down for unlimited time periods).

Macroinvertebrates were collected from two different substrate types (bedrock and gravel), each of which supports somewhat different communities of organisms. Sampling was performed monthly from September through February of each year. The test winter flow regimes were initiated in December of each year and continued through February. Samples were collected from locations that would be de-watered when the plant was shut down, but would be inundated at flows of 3500 cfs or higher. Statistical analyses were conducted to determine the extent to which and rate at which macroinvertebrate abundance changed in response to each test flow regime.

Data collected when the continuous minimum flow regime was in effect (1988/89) served as the baseline against which to compare the fate of the macroinvertebrate community when exposed to the intermittent test flow regime. Results during this flow regime provided a characterization of normal benthic community changes during the winter.

During the first year of what was intended to be a test of the intermittent flow regime (1989/90), high winter river flows resulted in nearly continuous plant operation, and thus precluded imposition of the intermittent regime for any substantial time period. No substantial change in macroinvertebrate abundance was found over the test period. Because the macroinvertebrates may not have been exposed to the test flow regime for a sufficient time period to experience effects, the test of the intermittent flow regime was repeated.

During the second year of intermittent flow regime (1990/91), only one of 22 combinations of taxa and substrates showed a decline during the test period that was greater than that observed under the continuous minimum flow regime. The conclusion was drawn that the intermittent flow regime had no significant negative effect on the macroinvertebrate community.

The third test regime was to be tested only if there were no demonstrable negative effects of the intermittent flow regime. Since this was the case, a test of the no-flow regime was completed (1991/92) and the results compared to the intermittent flow results. The results of the no-flow test regime were inconclusive. Although some macroinvertebrates appeared to be adversely affected in one habitat type, the abundance of all macroinvertebrates was extremely low in both substrates throughout the entire test period, making it difficult to determine if the absence of flow had caused any changes.

Because of the exceptionally low abundance of fauna occurring during the no-flow test year, a second year test of the no-flow regime was conducted (1992/93). Data from this second year of no-flow regime demonstrated that the absence of flow significantly affected the macroinvertebrate community in the bedrock habitat. The abundance of four of 11 macroinvertebrate taxa collected from the bedrock substrate decreased faster under the no-flow regime than under the intermittent flow regime, and total abundance of macroinvertebrates (all species) and abundance of one particularly important taxon (caddisflies, an important fish prey) decreased by a factor of 10.

Results from these studies support the recommendation that PECO provide a minimum flow of 3,500 cfs intermittently (with cessation of flow permitted for up to 6 hours followed by an equal or longer period of minimum flow) between December 1 and February 28.

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# INTRODUCTION

## REGULATORY BACKGROUND

The Philadelphia Electric Company (PECO) has historically operated the Conowingo Hydroelectric Facility as a peaking facility, generating near capacity at times of high demand (weekdays) and generating no electricity when demand is typically low (nights and weekends). During nongenerating periods, which could be lengthy during dry periods when river flows were low, the depth and velocity of water in the Susquehanna River downstream of the dam decreased to levels frequently detrimental to aquatic biota. Major fish kills occurred during the late 1960s, when large numbers of river herring, shad and other species were concentrated in isolated pools during plant shutdown and died of asphyxiation after consuming all available oxygen. Lack of continuous flows at other times of the year was suspected of having adverse impacts on other species of fish as well as other types of aquatic biota. When PECO applied to the Federal Energy Regulatory Commission (FERC) for renewal of the operating license for Conowingo in 1976, the impact of flow cessation on the aquatic ecosystem in the 10-mile river reach downstream of the dam became an issue requiring resolution.

During FERC relicensing, disagreements arose among PECO, state and federal agencies, and non-governmental organizations over the type and extent of impacts caused by Conowingo Dam operations and the measures that should be taken to alleviate impacts and enhance resources. These disagreements led to more than a decade of negotiation and litigation in FERC proceedings. Recognizing the likelihood that lack of resolution of these disagreements could result in continued expensive litigation, PECO, the State of Maryland, and other parties in the licensing process reached a settlement agreement in 1988 on three broad issues: 1) levels of minimum water flow releases from the dam needed to protect and enhance downstream habitat and aquatic resources; 2) measures necessary to ensure that water quality requirements (primarily dissolved oxygen concentrations) for water discharged from the dam would be met; and 3) steps needed to foster anadromous fish restoration.

Findings from site-specific studies sponsored by Maryland Department of Natural Resources, Power Plant Research Program (PPRP) in 1982 and 1983 (see below), provided the scientific foundation for elements of the settlement agreement that dealt with minimum flows that would be required during the spring, summer, and fall months. However, the parties agreed there was insufficient information available at the time of settlement to provide a sound scientific basis for selecting a minimum flow regime needed to protect and enhance aquatic resources during winter months (see sidebar). As a result, the settlement agreement specified that studies should be conducted to provide the data needed to resolve the winter flow issue.

**Excerpt from the Conowingo Settlement Agreement**

***MINIMUM FLOWS***

***1. The following schedule of minimum flows at Conowingo Dam, has been agreed upon by the parties hereto and is to begin on March 1, 1988, or upon approval by FERC of the Settlement Agreement, whichever occurs later. These flows represent turbine releases and do not include leakage.***

| *DATE* | *MINIMUM FLOW* |
|---|---|
| *March 1 - March 31* | *3,500 cfs* |
| *April 1 - April 30* | *10,000 cfs* |
| *May 1 - May 30* | *7,500 cfs* |
| *June 1 - September 14* | *5,000 cfs* |
| *September 15 - November 30* | *3,500 cfs* |
| *December 1 - February 28* | *3,500 cfs*** |

*** Studies will be implemented by DNR to determine if continuous flows have a detectable impact on benthic populations in the Susquehanna River below the Dam. Benthic population inventories will be conducted during continuous flows for the winter of 1988-89 and during interrupted flows for the winter of 1989-90, such interruptions not to exceed six reduced below 3,500 cfs except as provided in paragraphs 1 and 2 above.*

*Licensees and DNR agree that all biological (instream flow incremental methodology) studies previously ordered by FERC for the determination of minimum flows shall no longer be required.*

## TECHNICAL BACKGROUND

Extensive information was available at the time of the settlement agreement regarding anadromous fish stocks downstream of Conowingo (e.g., American shad, river herring, hickory shad). This information was available from studies conducted by PECO since the early 1970s to investigate fish passage issues at the dam. These same studies provided some data on the type and abundance of non-anadromous fish species present. The results of these studies and observations by PECO and state agency researchers suggested that, during the winter months, resident fish leave the shallow areas below the dam to reside in deep waters that might not be affected by cessation of river flow during plant shutdown. Anadromous fish are not present in this location during winter and would thus not be affected by winter flow releases.

More limited studies had been made of other components of the aquatic ecosystem, such as benthic macroinvertebrates. This group of biota consists of various life stages of aquatic insects, worms, and other organisms that live along the bottoms of rivers, and includes species such as mayfly and caddisfly larvae. Benthic macroinvertebrates are important food resources for fish. Because they are much more immobile than fish and cannot as easily leave an area that is in the process of being dewatered, they are the most likely of all ecosystem components to be affected by periodic decreases in the depth and velocity of water during plant shutdowns.

A number of studies funded by PPRP were conducted in 1982 and 1983 to evaluate the impacts of various river flows on macroinvertebrate communities and resident fish (PPRP-BLS-85-4, Weisberg and Janicki 1985). The results of these studies, in brief summary, showed that maintaining a continuous minimum flow from March through November increased the abundance of macroinvertebrates below the dam by nearly 100-fold (Figure 1). Two specific groups of benthic macroinvertebrates, chironomid midges and hydropsychid caddisflies, were enhanced to the greatest extent, and these two species are particularly important prey items for resident fish populations. Fish-feeding studies conducted at the same time showed that midges and caddisflies were significantly more abundant in the stomachs of three common fish species during years with a minimum flow from the dam than during years with periods of no-flow from the dam (Figure 2). These findings provided the technical basis for establishing spring, summer, and fall minimum flows specified in the 1988

settlement agreement.

A major concern regarding the potential adverse ecological impact of flow cessation during the winter was that dewatering and subsequent freezing of large portions of the dewatered river bottom could cause mortality of a substantial portion of the benthic invertebrates present. The loss of many such important prey items could be detrimental to fish below the dam. However, no data existed to establish the extent to which losses of benthic invertebrates might occur under different flow regimes, and it was clear that requiring unjustified continuous flows during the winter could impose a significant economic impact on PECO without concomitant ecological benefits. The settlement agreement thus stipulated that PPRP would sponsor a study of the effects of three winter flow regimes on the benthic macroinvertebrate community below the dam and that findings of this study would provide the basis for selecting an appropriate winter minimum flow regime for the facility by which all parties would abide.

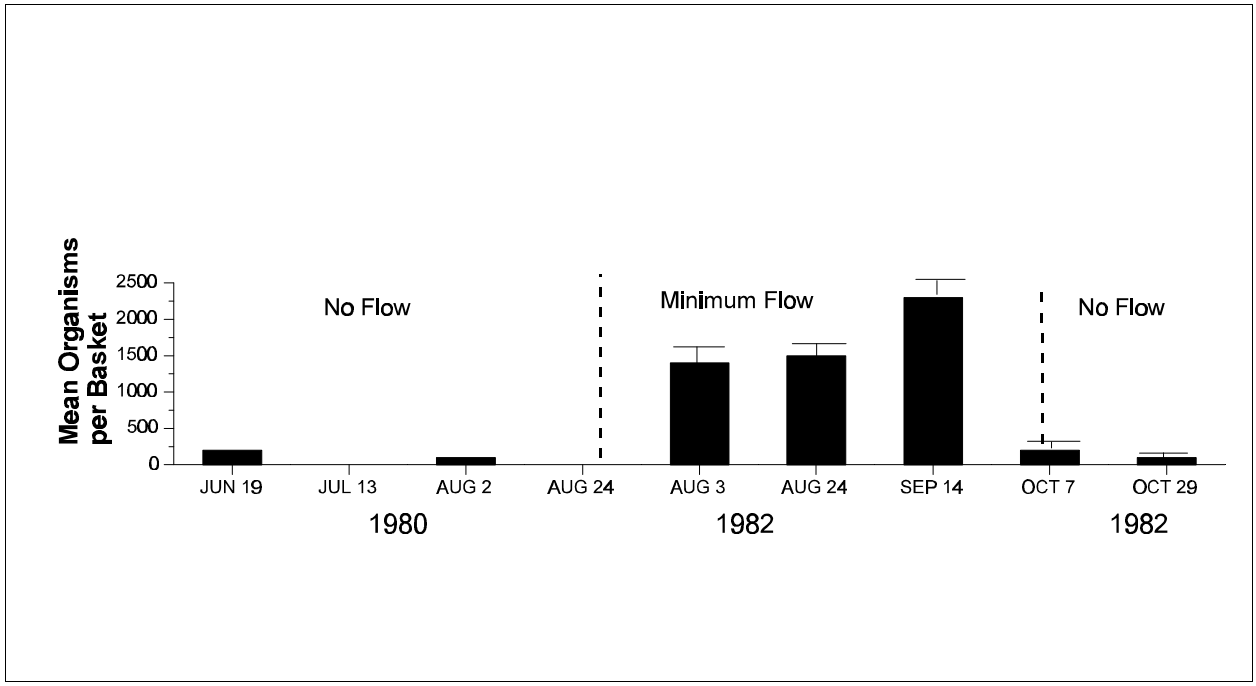


**Figure 1. Mean number of benthic organisms present in experimental containers (basket samplers) placed in the Susquehanna River downstream of Conowingo Dam in shallow habitat dewatered during no-flow conditions; tests were conducted in 1980 and 1982; from Weisberg and Janicki 1985.**

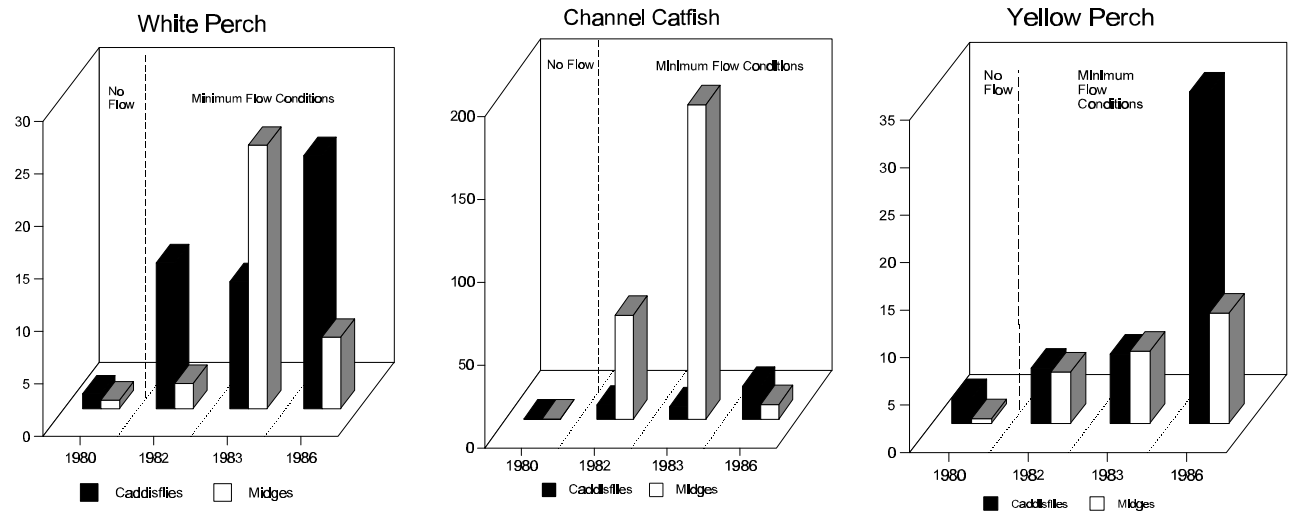


**Figure 2. Mean number of caddisflies and midges consumed by three species of fishes in the Susquehanna River downstream of Conowingo Dam under no-flow and minimum flow conditions; from Weisberg and Janicki 1985.**

## PURPOSE OF THIS REPORT

Versar, Inc., conducted the PPRP-sponsored benthic macroinvertebrate studies specified in the 1988 settlement agreement between 1989 and 1993. Copies of interpretive reports presenting comparisons between flow regimes are presented in Appendices 1 through 3*. This report provides an overview of the five-year study's findings, drawn from the individual interpretive reports, and provides the technical basis for recommending an appropriate winter flow regime appropriate for protection and enhancement of the aquatic biota living below the dam.

*An interpretive report was not prepared comparing the first year of the no-flow regime to the intermittent flow regime because overall macroinvertebrate abundances were extremely low throughout the test period making it difficult to detect abundance changes due to flow regime (see Results).

# METHODOLOGY

## ECOLOGICAL BASIS FOR FLOW STUDIES

All parties to the settlement agreement concurred that a flow regime that resulted in substantial impacts to benthic invertebrate communities below Conowingo Dam would not be acceptable as a permanent winter minimum flow. Aquatic insects and other benthic macroinvertebrates were selected as the biological community by which to evaluate benefits or impacts of different flow regimes for both ecological and logistical reasons.

Benthic macroinvertebrates hold a central role in riverine trophic structures. They are important processors and consumers of material inputs to the river system and are, in turn, an important source of food for many river fishes (Figure 3). Their importance at Conowingo Dam was documented in PPRP's 1982 and 1983 studies of the effects of minimum flows on resident fish growth and condition factor (Weisberg and Janicki 1985). Logistically, benthic macroinvertebrates have particular characteristics that make them ideal subjects for evaluation of flow effects, including their limited mobility (ensuring that the organisms taken in samples have been exposed to the environmental conditions that are the subject of the study), widespread distribution (ensuring that the findings at a number of limited locations represent the larger study area), and close association with the substrate (ensuring that the representativeness of the biological data collected at specific sites can be extrapolated to the broader areas based on knowledge of substrates).

Of greatest importance, however, is that many benthic macroinvertebrates are sensitive to and can be impacted by changes in flow regimes. Reduced flows and dewatering of substrates can result in stranding and desiccation and, in winter, freezing. Additionally, many species that are not exposed to air can

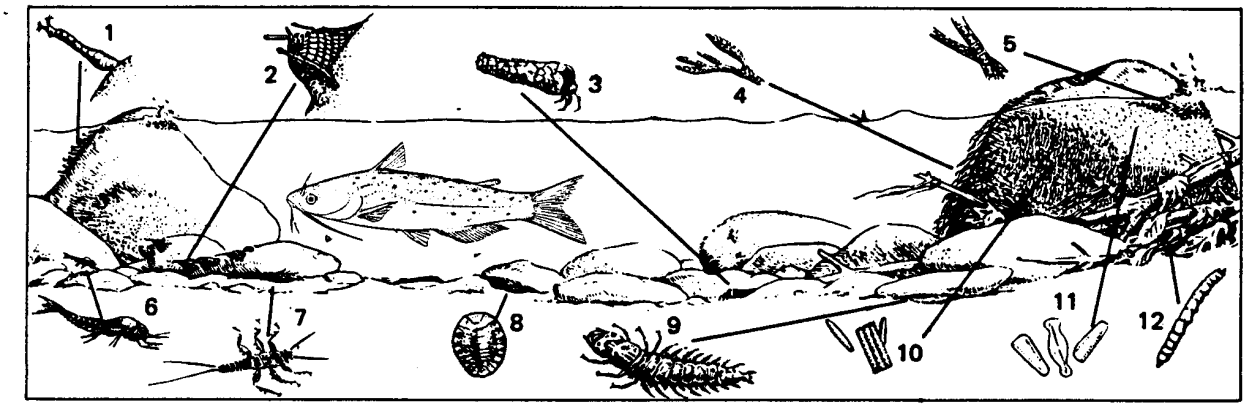


**Figure 3. Aquatic insects (fly larvae-1,12, caddisflies-2,3, mayflies-6, stoneflies-7, bettle larvae-8, and hellgammites-10) are important links between primary producers (water moss-4, algae-5, and diatoms-10,11) and resident fish species, such as the channel catfish, below Conowingo dam.**

be adversely affected by reduced flows and water velocity. Several macroinvertebrate species of great value as food items for important fish species, such as white and yellow perch and channel catfish, spin webs that allow them to breathe and capture food particles (Figure 4). Reductions in flow decrease the volume of water passing through these "nets" and thus reduce their efficiency for providing oxygen and sustenance to the organism.

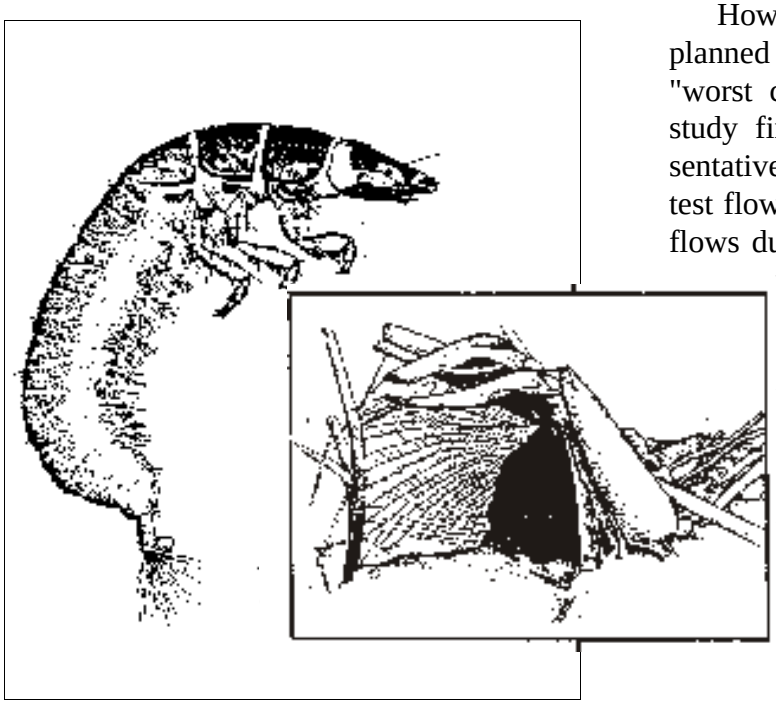

**Figure 4. The dominant caddisfly (*Cheumatopsyche* sp.) below Conowingo dam spins a net-like retreat to help supply oxygen and food particles.**

## STUDY DESIGN

The Conowingo Settlement Agreement stipulated that the state would evaluate three winter flow regimes, one in each of 3 years:

- a continuous minimum flow of 3,500 cubic feet per second (cfs);
- an intermittent minimum flow of 3,500 cfs (where cessation of flow is permitted for up to 6 hours followed by an equal or longer period of minimum flow; total time of flow cessation could not exceed 12 hours within a 24 hour period); and
- no required minimum flow (under which the plant could be shut down for unlimited time periods).

However, winter conditions in two of the planned study years differed from normal or "worst case" conditions to the extent that study findings were not considered representative of the potential consequences of the test flow studied. For example, winter river flows during January and February of 1990 were so high that plant shutdown seldom occurred and benthic macroinvertebrates were not exposed to plant shutdown conditions. As a consequence, studies of the intermittent and no-flow regimes took place over two year periods each (1989/90, 1990/91 and 1991/92, 1992/93; respectively). The data from the first year of the intermittent and no-flow regimes were discarded from use in interpretation and recommendation since these years were considered anomalous and unrepresentative as an appropriate test of the given flow regime.

Benthic macroinvertebrate communities were collected from two different substrate types, bedrock and gravel, each supporting somewhat different benthic communities. The samples were collected monthly from September through February of each year. The test winter flow regimes were initiated in December of each year and continued through February. Samples were taken from areas that would be dewatered during shutdown periods but not during flows of 3500 cfs.

A number of different characteristics of the macroinvertebrate community could be used to track their response to each flow regime. Simple abundance of important taxa proved inappropriate because large differences in abundance occurred between years in response to environmental variation other than flow release from the dam. Instead, analyses were conducted to evaluate the extent to which macroinvertebrates declined after imposition of the test flow regime by determining abundance before the imposition of the test flow regime (i.e., September through November) and comparing with abundance changes after the test flow was implemented (i.e., December through February). The rates of decline of the benthic community under each of the test flow regimes were compared to establish the extent to which the regimes' affects on the community differed.

# RESULTS

Data collected when the continuous 3,500 cfs minimum flow regime was in effect (1988/89) initially served as the baseline against which the fate of the macroinvertebrate community was compared when exposed to the other test flow regimes. During the year of continuous minimum flow, macroinvertebrate abundance generally remained constant or decreased from December to March. Natural decreases in benthic invertebrate populations during winter can occur normally due to predation and other forms of natural mortality, and to lack of new recruitment to the population.

During the first year of the intermittent flow regime (1989/90), no substantial change in abundance occurred over the test flow period (Appendix 1). However, high river flows resulted in continuous, rather than intermittent flows over most of the study period. Since this was an unrepresentative test of the intermittent flow regime, these findings were not useful for evaluation purposes, and a second year test of the flow regime was conducted.

During the second year test (1990/91), more normal winter conditions prevailed and intermittent flows occurred frequently during the test period. As an example of the results, Figure 5 compares the mean abundance of all macroinvertebrates in the gravel substrate during the continuous flow year with mean abundance during the two intermittent flow years. While a decline in abundance over the intermittent flow test period was evident, the decline was not statistically significant, and the absolute abundance of organisms was actually higher than abundance under the continuous flow regime. In this test, only one of 22 combinations of species and substrates showed statistically significant declines during the test period greater than the declines observed under the continuous minimum flow regime (Appendix 2). The conclusion drawn from the study was that the intermittent flow regime had no significant negative affect on the macroinvertebrate community.

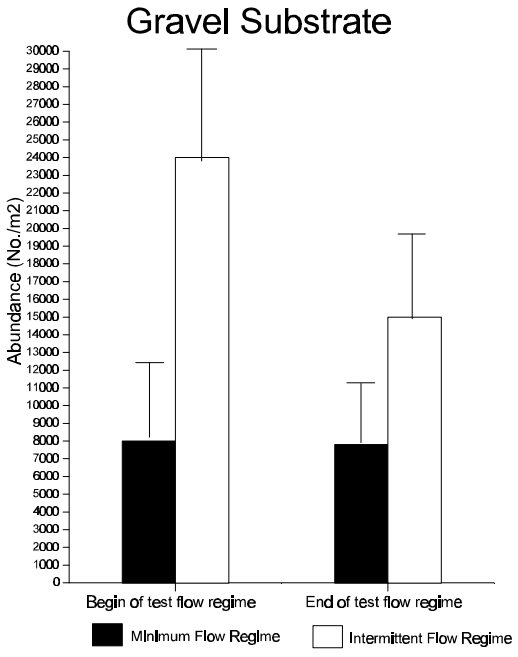


**Figure 5. Total mean abundance of macroinvertebrates collected from gravel substrate below Conowingo Dam under minimum flow (1988/89) and intermittent flow (1990/91) conditions.**

The third flow regime was to be tested only if there were no demonstrable negative effects of the intermittent flow regime. Since this was the case, a test of the no-flow regime

was completed in 1991/92. The results of the no-flow test regime were inconclusive. Although some macroinvertebrates appeared to be adversely affected in one habitat type, bedrock substrate (i.e., reduced abundance was noted), the abundance of all macroinvertebrates was extremely low in both substrates throughout the test period making it difficult to determine if the absence of flow had caused any changes.

Given the questionable representativeness of the results of the first test of the no-flow regime, a second year test of this regime was conducted in 1992/93. Data from the second year of the no-flow regime, when abundance of organisms was more normal, demonstrated that the absence of flow significantly affected the macroinvertebrate community in the bedrock substrate. The abundance of four of 11 macroinvertebrate taxa collected from the bedrock substrate decreased faster under the no-flow regime than under the intermittent flow regime (Table 1). For example, total abundance of macroinvertebrates and abundance of caddisflies decreased by a factor of 4 over the period during which the no-flow regime was in place (Figure 6, Appendix 3).

Table 1. Results of statistical analysis comparing rate of abundance decline under two different winter flow regimes. A (+) indicates a significantly higher mortality rate under the no-flow regime and a (-) indicates a significantly higher rate under the intermittent flow regime.

| Taxa | Bed-rock | Gravel |
|---|---|---|
| Total Abundance | + | NS |
| Chironomidae | NS | NS |
| Hydropsychidae | + | NS |
| Gammaridae | NS | - |
| Oligochaeta | + | NS |
| *Manayunkia speciosa* | + | NS |
| *Prostoma rubrum* | NS | NS |
| *Dugesia tigrina* | NS | + |
| *Menetus* sp. | - | NS |
| *Corbicula fluminea* | - | NS |
| *Ferrissia rivularis* | NS | NS |

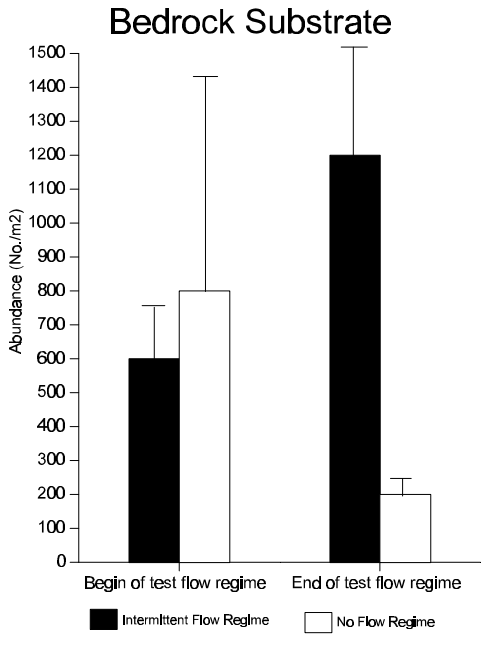


**Figure 6. Mean abundance of caddisflies (± 1 standard deviation) from the bedrock substrate below Conowingo Dam under intermittent flow (1990/91) and no flow (1992/93) regimes.**

## CONCLUSION

This study documented no substantial difference in effect on benthic macroinvertebrates between the 3,500 cfs continuous winter flow and the intermittent winter flow regimes. However, significant adverse effects to some biota in the bedrock habitat were documented under the no-flow regime. Implementation of an intermittent flow regime provides PECO with greater operational and economic flexibility than would implementation of a continuous minimum flow, while creating no documentable adverse ecological impacts. The data, therefore, supports the recommendation that PECO provide a minimum flow of 3,500 cfs intermittently (with cessation of flow permitted for up to 6 hours followed by an equal or longer period of minimum flow) between December 1 and February 28.

## REFERENCE

Weisberg, S.B. and A. Janicki. 1985. The effects of an interim minimum flow from the Conowingo Dam on fish feeding and benthos in the Susquehanna River. Prepared for Maryland Department of Natural Resources, Power Plant Siting Program by Versar, Inc., Columbia, MD. PPSP-UBLS-85-4.